The PLANETARY REPORT

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Mars at Crescent

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COVER: Mars was photographed by the Viking spacecraft on their approaches in 1976. Two orbiters and two landers surveyed and sampled the red planet, returning data on its weather, geology and lack of biology.

PHOTO: PLANETARY IMAGE FACILITY, JPL/NASA

In place of our regular Letters to the Editor, we are printing a letter written by Planetary Society member James Gotlieb to Congressman Sidney Yates, along with Mr. Yates's reply. Mr. Yates is a member of the House Appropriations Committee, which sets the funding levels for the various agencies of the government. Mr. Gotlieb's letter is an example of the power of the individual to "lobby" Congress—Ed

DEAR CONGRESSMAN YATES:

I am writing to ask you to use your position on the House Appropriations Committee to support continued funding for the NASA planetary program.

The 1970's saw an unprecedented growth in humanity's understanding of our place in the universe. Central to this remarkable extension of knowledge was NASA's planetary program. During the present period of reorienting budget priorities, NASA has not been immune. Crucial programs have been cancelled or delayed. The Venus Orbiting Imaging Radar (VOIR), the American spacecraft for the International Solar Polar Mission, the mission to Halley's Comet, and the research program on the Search for Extraterrestrial Intelligence (SETI) have all been cancelled.

The reason for these cuts is obvious. The space shuttle program is consuming an ever-larger proportion of NASA's budget. I have no quibble with the space shuttle *per se*. It is an extremely valuable investment which will revolutionize space exploration. The problem is that NASA is footing the entire bill for a project that will be used for military projects more than half the time. While these may be legitimate projects for a space vehicle, the budgetary arrangements are forcing the poor civilian cousin (NASA) to subsidize its wealthier relative in the Pentagon—a relative who, like Croesus, already has more money than he can prudently spend. This arrangement is ridiculous, unfair and just plain bad public policy.

The curtailment of the planetary program has at least three negative effects:

1) We will know less about ourselves and our place in the universe. On the level of pure knowledge we will be far poorer.
2) Budget cuts mean personnel cuts and personnel cuts mean fewer positions for young astronomers, astrophysicists, planetary biologists and others. This means that space science will lose many of the finest minds of this generation—the scientists who would otherwise have formed the human capital for future space exploration.
3) Space exploration is one highly visible, relatively inexpensive, and very productive undertaking which can unite our divided planet. The stars stir everyone's imagination and the exchange of scientific information enhances communication between otherwise antagonistic countries. No other activity can so clearly reinforce the fundamental truth that before we are American, Russian, Chinese or Tanzanian, we are human beings on Earth who must "dress and keep" our garden if any of us are to survive. Loss of the planetary perspective, which only an active space program can provide, makes our parochial conflicts loom larger than they actually are, thereby increasing selfishness, misunderstanding and the likelihood of war.

Shifting a portion of the shuttle's budget to the Department of Defense, or making the Pentagon pay its own way, would make more money available for NASA's planetary program, thereby increasing our understanding and our chances for survival.

Please support NASA's planetary program.

JAMES GOTLIEB, *Chicago, Illinois*

DEAR MR. GOTLIEB:

Thank you very much for your letter regarding NASA's planetary program.

Your views are thoughtful and very well stated. I am impressed by the force and eloquence of your arguments. As you may know, the NASA budget is within the jurisdiction of the HUD and Independent Agencies subcommittee of the Appropriations Committee. You make a number of telling points, particularly concerning the responsibility of the Pentagon to pay for military space programs, and I intend to pass your views along to my colleagues on the HUD-Independent Agencies subcommittee.

I appreciate your concern—and your taking the time to express it so vividly.

SIDNEY R. YATES, Member of Congress

ALL'S IN FREE

A CELEBRATION AND A LAMENT

by RAY BRADBURY

No more the roofing of the sweet ball high
With: "Over, Annie, over!"
The astronauts drown deep in rye and clover.
The games they played are put away in weeds
While fireflower seeds
Spring up toward Moon but, failing, fall
Where old schemes sour.
What once was sunrise hour of basking dream
Where all our souls stood gantry brave,
Now knows a southern grave, Apollos' rust.
What was cosmic lust, grist for all mankind,
Now, its purpose blind, all trystless, aimless goes.
Where God's children once played survival's game
Now the name no name and the rules forgot.
Now the last tag stops and no tagging back,
Now all's lose and lack where we won with Play.
Where our hopscotch lay chalked across the stars
To Braille-finger Mars as the Lander sought
Where our bright wits taught us to climb the noon
Now our jackstraws strewn as our chessmen cease.
In the sky? No torch. All is front porch peace
As our heartsore race folds its dreams to bed,
Goes to sleep half-dead, yearns to be alive,
Hopes to thrive late nights when from fields of clover,
Whisper astronauts: "Over, Annie, over!"
As ghost rockets fire our high chimney beams
To recall bright dreams, bright Moon, bright Mars.
From the highest stars on the Cosmic Tree
Echoes:
"All's in, all's in, all's in Free!"

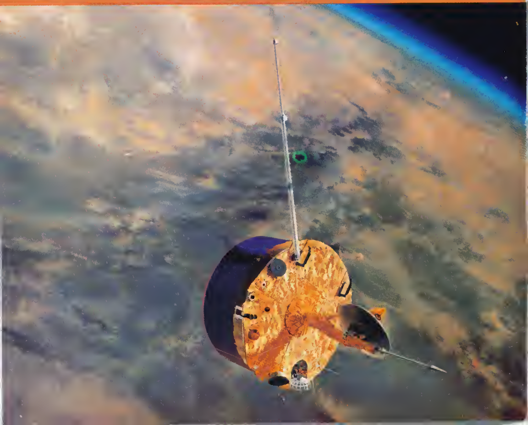
SOUNDS FROM SPACE

by Frederick L. Scarf

Imaging systems on spacecraft serve as extensions for our eyes, and in a sense they allow us to journey along to new vantage points and to participate directly in the exploration of new worlds. These systems have now provided us with many remarkable space pictures of Earth and its Moon, and with close-up views of the craters on Mercury, the clouds and surface of Venus, and the varied terrain of Mars as well as its satellites. The *Pioneer* and *Voyager* flybys of Jupiter and Saturn delivered astounding pictures of enormously complex and beautiful planetary systems, and the images themselves contained completely new information about many important phenomena. The pictures told us about the structure of Saturn's rings, the volcanos on Io, and the dynamic circulation patterns in the vast storm system that we used to think of simply as a giant red spot on the disk of Jupiter.

The idea that a spacecraft system can act as a robot eye is a common one, but the corresponding acoustical concept—that a remote recorder can capture sounds from space—is still relatively unfamiliar. We tend to think of space as a complete vacuum, and we also think of sounds only in terms of pressure variations in a gas. Thus, at first glance, it would appear that sounds could not develop above the dense atmosphere. While this straightforward reasoning is correct for acoustic signals that could be heard by the human

The Pioneer Venus Orbiter reached the shrouded planet in December, 1978. Scientists expect the spacecraft to continue to transmit data until its orbit decays, sometime in 1992. The plasma wave instrument, resembling a "rabbit ears" television antenna, protrudes from the right side of Pioneer as portrayed here. This instrument has returned much information on the interaction of Venus and the solar wind.



ear, it turns out that spacecraft systems called plasma wave instruments really do record space sounds using electric or magnetic sensors in place of ordinary microphones.

The equipment for a plasma wave investigation is quite simple. The electric sensor can be a single length of wire similar to a car radio antenna, or a V-shaped set of wires similar to the rabbit ears or dipoles used to receive television signals. The magnetic sensor is a loop or coil of wire, and the electronics unit is basically a high-fidelity audio amplifier whose output goes to the spacecraft tape recorder or to the data transmitter. In essence, the customary plasma wave investigation resembles a simple portable cassette recorder with a car radio antenna connected to the microphone input plug. We listen to the audio frequency signals that develop on the electric antenna just as if we had connected a loudspeaker or a pair of headphones directly across the rabbit ears. However, it must be remembered that these audio frequency signals are electrical oscillations, and they would not stimulate responses if we were to use an acoustical microphone (or a human ear) rather than an antenna which serves as an "electrical microphone."

Interest in the analysis of audio-frequency waves from space started long ago. During World War I, when ground-based antennas and amplifiers were used in attempts to eavesdrop on enemy telephone conversations, the soldiers would frequently hear strange and intense whistling sounds. Studies of these whistlers continued for many years, and scientists speculated that they came from above the atmosphere. But until the early 1950's, the explanation for the sounds remained highly incomplete. One key to understanding the whistlers was the recognition that atmospheric lightning strokes provided the intense, broadbanded radio noise bursts that serve as the impulsive sources for these signals. A second key factor involved the realization that the region of space above the atmosphere is *not* a vacuum. We now know that the rarefied gas surrounding the Earth's atmosphere is so hot that all of the atoms are fragmented into charged ions and electrons. This charged gas, called a plasma, has properties that strongly affect the propagation of very-long-wavelength radio waves, and this ultimately leads to the conversion of the original dissonant lightning discharge noise burst into a whistling tone with almost musical properties.

Figure 1 shows how the audio pattern develops. The long-wavelength radio waves generated by the lightning stroke propagate out beyond the atmosphere along the direction of the Earth's magnetic field, but the plasma in space makes the waves travel relatively slowly. Moreover, the wave speed actually depends on the frequency, so that the higher-frequency components move out more rapidly. Thus, a detector on the ground in the opposite hemisphere receives the high-frequency tones first and the signals with lower frequencies arrive later, creating a whistle with continuously descending pitch.

The analysis of whistler propagation provides valuable information about the distribution of plasma in the region controlled by the Earth's magnetic field (the magnetosphere), and when it became possible to send scientific instruments into orbit on spacecraft, it was natural to try to perform some wave measurements in space. The first opportunity came in 1959 when *Vanguard 3* was launched; the spacecraft magnetometer had a coil that was used as a magnetic antenna for detecting audio frequency waves, and this instrument frequently detected lightning whistlers.

The early *Vanguard 3* measurements were followed by many others, and the waves detected in Earth orbit using magnetic antennas included low-frequency electromagnetic emissions spontaneously generated within the magnetospheric plasma. The names given to these waves reflect the fact that the scientists were actually analyzing the sounds; we find references to tweeks, swishes and clicks, as well as rising whistlers, hiss and chorus (the chorus sounds resemble those that might come from a flock of chirping birds). Most of these magnetospheric waves travel slowly in the plasma, just as lightning whistlers do, and scientists have determined that these plasma waves interact very strongly with energetic electrons trapped in the Earth's Van Allen belts. **Figure 2** shows how this happens. The Van Allen belt particles move in spiral orbits guided along the direction of the Earth's magnetic field, and the waves also travel back and forth along the field. When an electron moves at just the right speed to interact with a wave, the orbit of this electron is changed and it breaks free of the Van Allen belt. The effect of this resonant interaction is reminiscent of the disturbances in a car moving along a bumpy highway; at a particular resonant speed, the car starts to vibrate, and it may come apart. Here, the electron comes out of the magnetosphere and falls into the atmosphere, producing the atmospheric disturbances indicated on the figure. This example demonstrates that plasma wave measurements in space are not simply conducted to record unusual sounds. The wave instruments are flown because we now know that the state of the planetary

Figure 1

Figure 2

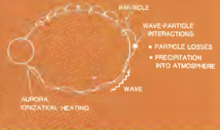


Figure 3

Figure 4

magnetosphere is dominated by interactions between plasma waves and charged particles

When plasma wave investigators started to fly electric antennas on spacecraft toward the end of the 1960's, they detected the familiar electromagnetic waves plus an entirely new class of important plasma oscillations with no magnetic components at all These new "electrostatic" waves involve compressions and rarefactions just as ordinary sound waves do. But in the dilute plasma of the magnetosphere, the gas pressure is so low that the pressure variations are below threshold for a microphone. However, in the plasma, the compressions and rarefactions of the ions propagate out from the source, as shown in **Figure 3,** and the fluctuating density of charged particles produces fluctuating electric fields which can be picked up on an electric antenna. Thus, the "electric microphone" detects short-wavelength acoustic-type waves as well as long-wavelength radio waves.

The most violent of these sound waves are generated near the interface between the streaming plasma from the Sun (the solar wind) and the magnetosphere Here the interaction produces a "bow shock" which is characterized by intense and variable turbulence levels, with sounds similar to crashing bursts of thunder. Protons and electrons heated at this shock stream back toward the Sun at high speeds, and in this precursor region, they radiate chirping electron plasma oscillations and ion acoustic noise bursts, just as a supersonic airplane leaves behind a trail of sonic booms.

The *Pioneer* Venus spacecraft began providing the first plasma wave observations from another planet when it entered orbit around Venus on December 5, 1978 The *Pioneer* wave instrument, shown in **Figure 4,** is a compact device with 28-inch-long rabbit ears deployed directly from the spacecraft. The electronics unit doesn't transmit the full audio signal back to Earth; audio amplifiers simply measure the wave levels at four fixed frequencies. Nevertheless, this basic instrument has yielded much new information on the Venus-solar wind interaction, including data on the bow shock and the comet-like plasma tail which stretches out behind the planet.

Late in December, 1978, a pair of Soviet wave instruments arrived on the *Venera 11* and *12* descent vehicles These systems, which operated within the dense atmosphere of Venus, used magnetic antennas and detected electromagnetic waves from lightning Whistlers from Venus lightning were subsequently discovered in the *Pioneer* Orbiter data, and joint studies of the observations from the U.S. and U.S.S.R wave investigations are proceeding In March, 1982, the *Venera 13* and *14* descent vehicles made new measurements of Venus lightning, and because the Orbiter plasma wave instrument has remained in continuous operation, new correlation studies are planned.

When *Voyager 1* swept past Jupiter's magnetosphere in March, 1979, its plasma wave instrument provided the first real sounds from another planet. The *Voyager 1* and *2* wave systems use 30-foot rabbit ear antennas, and measure wave intensities at 16 fixed frequencies In addition, the instruments have wideband audio amplifiers which directly record the fluctuating antenna voltages The very high transmission capability of *Voyager* is most often used to send video images back to Earth, but in a special mode this capability transmits sounds from the wideband channel of the plasma wave instrument. *Voyager* can "listen" to the environment around the spacecraft, and this provides us with a set of robot ears.

We now know that many of the sounds from Jupiter and Saturn differ in subtle ways from those detected at Earth; plasma waves in the outer planet magnetospheres generally have lower frequencies and slower temporal variations so that the strongest waves occur right in the middle of the audible spectrum and we can listen to them using ordinary audio equipment In the audio range, the signals detected at Jupiter included upstream electron plasma oscillations, ion acoustic waves, a crossing of the bow shock, trapped radio waves, chorus, and even lightning whistlers, together with sounds of assorted spacecraft activities (thruster firings and mechanical motions of other *Voyager* subsystems), and many more complex acoustic waves.

These plasma wave measurements provided a wealth of important information that helped us to understand the structure and dynamics of Jupiter's magnetosphere For instance, the *Voyager 1* plasma wave instrument detected very intense chorus emissions within the huge doughnut-shaped torus of plasma generated by the volcanos on the moon Io. These chorus signals cause low-energy electrons from the magnetosphere to precipitate rapidly into Jupiter's atmosphere, leading to intense auroral emissions, as indicated in **Figure 2.** Thus, the measurements of plasma waves in the Io torus provided unexpected data on the complex coupling between the volcanos of Io and the Jovian aurora.

The observations of the trapped radio waves at Jupiter led to very different information. The analysis of the wave characteristics provided knowledge about the concentration of plasma electrons, even in the rarefied high-latitude tail region where the density was found to be as low as one electron in every 100 liters of space. The detection of essentially the same trapped radio waves two years later established that *Voyager 2* had reentered Jupiter's magnetic tail on its way to Saturn. We had identified Jupiter's magnetic tail over a distance of about five astronomical units (one AU is the distance from the Sun to the Earth, about 150 million kilometers), and this vividly showed how the giant planet is itself dwarfed by its immense magnetosphere.

At Saturn we had far fewer opportunities to listen to the plasma waves and, while *Voyager* did not obtain wideband recordings of the bow shock or lightning whistlers, it did detect other classes of sounds In addition, when *Voyager 2* crossed Saturn's ring plane, the plasma wave instrument detected a storm of intense impulsive noise bursts that produced the sounds of hail on a metal car roof; these signalled the impacts of ring particles on the spacecraft. The audio link actually allowed us to hear Saturn's rings from a distance of a billion miles The analysis of the data in the wideband recording is now yielding information on the sizes and the spatial distribution of these ring particles

Because there were so few opportunities to listen at Saturn using the *Voyager* wideband audio amplifier, we developed another way to hear the waves The measurements from the 16 fixed-frequency channels were used with a small computer to drive a 16-voice music synthesizer. At TRW we then constructed the sounds of the Saturn bow-shock crossings, the Titan flyby and the 20-minute interval around the ring-plane crossing The synthesis technique yielded very pleasant and almost musical results, and this program has now been applied to reconstruct sounds from the wave instruments on the *Pioneer* Venus Orbiter and from other spacecraft that do not have the full audio capability.

The TRW Space and Technology Group has combined some of these Saturn sounds with a brief narration and produced a soundsheet which can be played on a phonograph A limited number of copies are available to members of The Planetary Society. If you would like a copy of these "Sounds of Saturn," please write to The Planetary Society, Sounds of Saturn, P.O Box 91327, Pasadena, CA 91109. A donation of $1.00 to cover postage and handling would be appreciated.

Fred Scarf, of TRW's Space and Technology Group, is the Principal Investigator for the plasma wave instruments now operating on Voyagers 1 *and* 2, *the* Pioneer *Venus Orbiter and the International Sun Earth Explorer 3*

Charting a Course for Spaceship Earth:

Humankind in the Solar System

by Brian O'Leary

We are at a critical juncture in solar system exploration. On the drawing boards are dozens of promising ideas, many which could be realized in the coming decades. There is plenty of incentive for human expansion into the solar system, yet there is no long-term commitment and no consensus on how or when it will occur.

This past May, at the fiftieth anniversary celebration of the American Institute of Aeronautics and Astronautics (AIAA) held in Baltimore, Maryland, a panel addressed these issues. Members of The Planetary Society and the National Space Institute filled out the audience, along with some familiar faces—author James Michener and *Apollo 11* astronaut Michael Collins. The panel's charter was broad: to address what humans and machines could do in space over the next 50 years.

Louis Friedman, The Planetary Society's Executive Director, chaired the panel, which included Benjamin Finney of the University of Hawaii, Tom Rogers of the National Academy of Sciences's Space Applications Board, Carol Stoker of the University of Colorado, Ben Bova of *Omni* Magazine and myself. In his opening remarks, Friedman stressed a "continuing partnership between the role of humans and the role of machines in exploring the solar system." He said that, while he has been struck by the continuing debate on manned versus unmanned space exploration, there will be significant roles for both. This view was later echoed by other panel members.

The panelists spoke in the temporal order of their topics, from historical analogues to the far future. Ben Finney began with a richly-illustrated discussion of early human expansion across the oceans. Citing numerous examples of some nations willing to risk long voyages while others bowed out, he warned that the United States risks losing its leadership in solar system exploration. History has repeatedly shown that abrogating such leadership can have enormous long-term societal consequences.

Finney gave the example of the rise of the Portuguese and the fall of the Chinese in maritime activity during the fifteenth century. Turning inward, the bureaucratic leaders of China had all but stopped their people's seafaring. By the year 1500, it became a capital offense in China to build a sea-going junk with more than two masts.

"Had the Chinese kept going," said Finney, "had they rounded the Cape of Good Hope, sailed north, then anchored off Lisbon, explored the Thames or cruised the Mediterranean, all of which they were technically capable of doing, how differently the modern world might have turned out."

European countries one by one—first Portugal, then Spain, then Holland, then England—rose and fell in maritime leadership. In each case the retreat had negative economic effects lasting for centuries. In this light, Finney expressed concern about NASA's stagnant budget. "Does this mean our space program is in danger of going the way of the Ming Dynasty navy?" he asked. "I do not think so, although the specter might be useful for badgering your congressman, or the President, when he says we cannot afford to spend more on space." Finney speculated that Japan may take over our lead in space exploration if there is not a turnabout in U.S. policy.

The other lesson to be learned from oceanic exploration, according to Finney, is that new forms of political and economic organization are required. What forms will they take? Currently they are impossible to predict, but he described the Polynesian voyages in the Pacific as the most pertinent analogue: for millennia, these Stone Age explorers had reached new lands previously unsettled, from which their descendants would eventually push on and colonize still more lands. Speculating on our future, Finney concluded that, "Employing new technologies, new forms of social organization, these space-adapted people will be the Polynesians of humanity's odyssey among the stars."

The second speaker was Tom Rogers, who, with decades of experience in the technology policy field, presented an unusually refreshing discussion on the near-term role of humans in space. Confessing that "I am only a scientist, and engineer, and worse yet, a sometime public administrator," Rogers urged that the interests of a much broader community be represented.

The debate on human versus machine, he said, was irrelevant for now because little that is new will happen in space in the next decade, and by the 1990's the state of the art of robotics and computers will have changed too rapidly to predict. Stressing again that only a narrow range of interests has been represented in the debate, he stated that people's emotions need to be considered. The question is, do machines or *I* want to go into space? People will be able to put both people and machines into space, but machines will not be able to put people and machines into space.

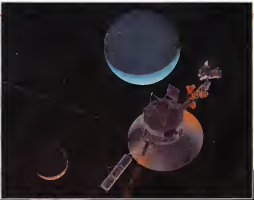
"You will look hard and long in the AIAA publication," Rogers went on, "to find such words as 'beauty,' 'compassion,' 'joy,' 'surprise,' 'awe,' 'pride,' etc., and you will not often read of machines in space that are expected to laugh, to shout, to have friends, to cry, to dance, to dispense justice or to embrace one another. And, yet, the essence of human experience and endeavor is to be described in such words and actions—words and actions that have little if any meaning to machines and their use."

Rogers made these practical recommendations: 1) we all communicate our views on space legislation to Dr. George Keyworth's Office of Science and Technology Policy in the Executive Office of the President, and to our senators and representatives, in broad, human-oriented language; 2) the engineering community develop innovative high-energy propulsion systems to reduce the cost of space transportation; 3) cooperative international efforts be

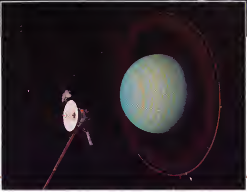
(continued on page 9)

RIGHT:
Voyager 2 looks back upon Neptune and its moon Triton after the spacecraft's closest approach to the planet on August 24, 1989.

BELOW:
In this artist's rendering of a possible future mission, a spacecraft based on the RCA TIROS-N satellite makes a low pass over an asteroid.



PAINTING BY DON DAVIS FOR JPL/NASA



PAINTING BY DON DAVIS FOR JPL/NASA

LEFT:
We will have to wait until 1986 for the next planetary encounter, when Voyager 2 will flyby Uranus, seen in this painting with its nine known rings.

(continued from page 7)
pursued to open up human space travel to people from a wide variety of disciplines, beginning with short visits to space in the shuttle; and 4) leaders from large labor organizations and industry collaborate with the Department of Labor and NASA to prepare skilled wage-earners for employment in space.

Panel chairman Friedman presented a well-illustrated discussion of plans for future planetary exploration, based on studies carried out over the past few years at the Jet Propulsion Laboratory. The only authorized new mission is *Galileo*, an orbiter that will circle Jupiter, repeatedly encountering its Galilean satellites, and a probe designed to enter the Jovian atmosphere to measure its vertical structure (see *The Planetary Report*, March/April 1982). The launch is currently scheduled for 1986, with Jupiter encounter in 1988. Friedman also presented plans for *Voyager 2* to encounter Uranus in 1986 and Neptune in 1989.

Other missions under consideration but not authorized are the Venus Radar Mapper, which would give a good all-weather look at Venus's surface; an automated lunar base and rover that would be analogous to an unmanned Antarctic outpost, a Mars rover and airplane to obtain a much more thorough look at the Martian surface; and concepts for missions to Saturn, Titan, Uranus, Neptune, Pluto, the asteroids and comets. Friedman lamented that the United States does not plan a Halley's Comet mission for its once-in-a-lifetime appearance in 1986, while the Soviets, Japanese and West Europeans will all send spacecraft to the comet.

Friedman stressed that these proposed missions would not necessarily require expensive, esoteric new technologies; many would involve low-cost, off-the-shelf hardware. Only a small fraction of NASA's budget would be required.

I took the podium to describe recent proposals for the use of extraterrestrial materials for space manufacturing and for use on Earth. Several engineering studies undertaken over the past several years have concluded that, with an initial investment of a few billion dollars, it will become possible to extract pure elements from lunar or asteroidal materials. Products such as lunar oxygen for rocket fuel, lunar silicon for solar collectors, and asteroidal platinum delivered to Earth could justify such an investment with the productivity doubling and redoubling every few months.

Studies suggest that several of the Earth-approaching asteroids and the Martian moon Phobos could provide resources recoverable in near-Earth space more economically than the Moon could provide. Further cost reductions come from double lunar gravity assists, planetary gravity assists, atmospheric braking, and the use of existing hardware.

Particularly promising is the potential use on Earth of asteroidal platinum-group metals which are enriched, in some cases, twofold over the richest terrestrial platinum-group ores. Because of the great economic and strategic value of platinum, the mining of asteroids is not as futuristic and far-fetched as might be thought: one space shuttle cargo bay of platinum landed on Earth would be worth $1 billion at today's market prices.

Carol Stoker gave some thought-provoking and well-reasoned arguments for the human exploration of Mars. Much of her presentation was based on a workshop held in Boulder a year ago when a variety of scientists and engineers gathered, under Planetary Society co-sponsorship, to consider these questions.

Workshop members proposed a series of precursor missions that would include a water-mapping polar orbiter, high resolution imaging of potential landing sites, sample return, and a Phobos/Deimos manned precursor. This last idea, Fred Singer's "Ph-D proposal," is exciting not only because the Martian moons could serve as base camps for the human exploration of Mars, but also because of their accessibility in terms of energy and cost, it is possible that Phobos and/or Deimos could become the cheapest sources of water in the solar system and so could be used as fuel depots and prime sources of extraterrestrial materials.

Stoker discussed the possibility of utilizing Martian resources, developing long-duration life-support capabilities, optimizing spacecraft designs and propulsion systems, and analyzing what could be explored on the surface. If we look at the dovetailing of rationales—exploration, mining resources, fuel depots, etc.—the case for Mars would appear to appeal to a broad community of space advocates. She concluded that "Manned Mars exploration may be just the thing we need to get public acceptance of continuing our presence in space." The investment in the first manned expedition, according to Stoker, would be comparable to that for the space shuttle.

Omni Editorial Director Ben Bova (a last-minute replacement for Gene Roddenberry, the creator of "Star Trek") concluded the session with some philosophic views of the future. His first remarks concerned the feasibility of interstellar travel. Because the stars are so far away, we have only three choices: 1) build an ark that would journey across the vast reaches for generations, 2) go fast—close to the speed of light—so that the trip would take a generation or less, or 3) take a short-cut, a "space-warp" that could perhaps use black holes as accelerators. While the last of these is speculative, Bova suggested that several dedicated scientists and their families would be more than happy to attempt either of the first two possibilities. He echoed Finney's sentiments that the early Polynesian voyages provide a good analogue.

Bova stressed human survival as a rationale for the permanent human presence in space. While we have the power to destroy, we also have the chance to preserve ourselves by inhabiting the far reaches of the heavens. There is also the problem of myopia. "The average American is excited by 'what's in it for me,'" he lamented, "but not for the joy of exploration." Bova argued that new knowledge leads to new technology and more freedom for us all. Unfortunately, we live in a time when immediate results are foremost in people's minds, only short-term considerations seem to justify what needs to be done. Bova pointed to The Planetary Society's efforts in stressing exploration and new knowledge as essential forerunners of humanity's expansion into the universe.

In the discussion that followed the presentations, a consensus emerged among the panel members and the audience: the exploration of space and its abundant worlds—by both humans and machines—is of immediate and essential importance to all our futures. But we will need to take a broader view and more active role in taking that consensus to the public. And we must do it now.

Brian O'Leary is an astrophysicist, writer and former astronaut. He is working for Science Applications, Inc. in Redondo Beach, California.

THE **VIKING** LEGACY

BY JOHN SPENCER

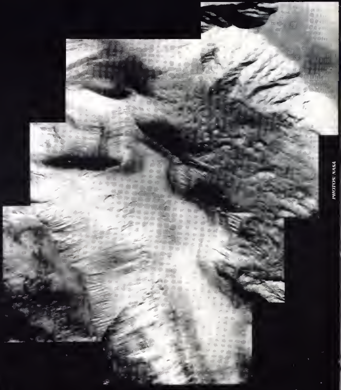
The *Viking* Project, humanity's most concerted scientific assault yet on the mysteries of another planet, is now almost over. Of the four original spacecraft, *Viking* Lander 1, standing on the brown plains of Chryse, alone keeps our presence alive on Mars.

Imaging data, part of the legacy of the *Viking* missions, are stored on miles of computer tape at the Jet Propulsion Laboratory, and in more accessible photographic form in data centers around the world. Over 100,000 images, taken from orbit and from the ground, show us Mars in splendid detail. Only a tiny proportion of these pictures have ever been publicly released; the data set is so huge that few planetary scientists have seen more than a sample. So here are a few more of those 100,000 plus pictures—a reminder of the new heights of our knowledge and continued depths of our ignorance about the Red Planet.

JOHN SPENCER IS A GRADUATE STUDENT IN THE DEPARTMENT OF PLANETARY SCIENCES AT THE UNIVERSITY OF ARIZONA AT TUCSON

Mysterious Canyon—This *Viking* 1 mosaic shows part of the Martian canyon Hebes Chasma, north of the main Valles Marineris canyon complex. The existence of this canyon, which is a completely closed, 6-kilometer-deep, 320-kilometer-long hole in the ground, is a major headache for those scientists brave enough to attempt an explanation of the Martian canyon system as a whole. Material cannot be moved sideways out of the Chasma, by the flow of water for example, because there is no breach in the wall of cliffs enclosing it. Its oval shape is not the expected shape for a canyon formed by downdropping of the crust along geological faults and wind erosion is probably too weak to gouge out the missing 82,000 cubic kilometers of rock.

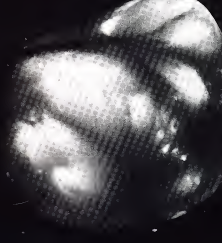
Whatever its origin, Hebes Chasma provides some of Mars's most spectacular scenery. This high-resolution oblique view shows a central mountain rising five kilometers above the rubble-covered floor. Its terraced slopes look very different from the gullied bounding walls of the Chasma. Similar layered mountains occur in other parts of the Valles Marineris system. Do they record the filling of the entire complex with layered sediments which were then partially re-eroded, so that the canyons were excavated twice? We may not know the answer until a geologist, rockhammer in hand, can scramble among the cliffs and gullies of this stupendous structure and investigate it in person.



PHOTOS: NASA

A Martian Blob?—The subject of this bizarre image will be unrecognizable even to many who think they are familiar with the solar system's geography. It is Deimos, Mars's tiny outer satellite, whose diameter is only about 13 kilometers. It looks so unfamiliar because of the unusual lighting; the Sun is directly behind the spacecraft so, as in a view of the full Moon from Earth, there are few shadows visible to bring out surface details such as craters. All that can be seen are albedo features—patterns of light and dark material on the surface.

Deimos is strangely shaped: its surface consists of several gently curved "facets" separated by rather sharp ridges, so that it resembles a water-worn brick. Bright material on the ridges can be seen to be drawn out in streamers towards the centers of the facets, probably because it is being pulled "downhill" by Deimos's feeble gravity, less than one-thousandth that of Earth. That gravity is important even on such a tiny object is quite a surprise. No similar streamers are seen on Phobos, Mars's other small moon, which has quite a different appearance, being heavily cratered and fractured—a hint of the variety we may find when we explore other small worlds in the asteroid belt. [Thanks are due to Dr. Peter Thomas of Cornell University for providing this photograph.]



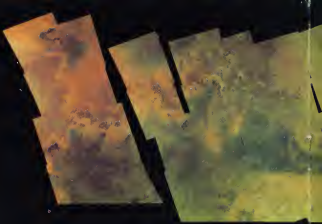
Ancient Flood Channel?—Shown here is a 65-kilometer-long section of the floor of Kasei Vallis, a large Martian channel that flows into Chryse Planitia, where Viking Lander 1 stands, from higher ground to the west. Although new theories appear from time to time, most scientists are still inclined to believe that this and other large channels were cut long ago by huge, catastrophic floods of water.

At the high resolution of this view, a more complicated geological story unfolds, one which we poorly understand. To the north of the central valley is an area that was scoured by the flooding, and to the south is a higher plateau with a strangely-sculpted surface of cracks that may have escaped the worst of the flood. The valley floor is smooth with very few impact craters, and buries what may be a landslide emerging from a gully in the south bank at the left of the picture. The rim of a large crater on the north bank is also partly buried. These are clues showing that the valley floor is much younger than the landscape around it, and so wasn't deposited by the same flood that created the valley: maybe a smaller, later flood was responsible. Using such arguments, the history of a region like this can be carefully unravelled and our understanding of this complex planet can be improved.

The Equatorial Region—One problem with the Viking Orbiter cameras is their very narrow field of view, necessary to show the Martian surface in the greatest possible detail but inconvenient for studying large-scale features such as the light and dark albedo markings that give Mars its characteristic appearance when seen in a telescope from Earth. Large areas could be covered by sequences of overlapping frames taken from a high point in Viking's eccentric orbit, but even then broad patterns tend to be confused and hidden by the sharp boundaries and brightness variations between adjacent frames in the mosaic.

The solution to all this involves using the computer to remove differences in tone between images, correct for distortions caused by changes in viewpoint, and blend all the frames into a smooth mosaic in which individual images lose their identity. This picture shows the results of such a process, applied to images taken through three different color filters to make a natural-color mosaic of a 4000-kilometer-long sweep of Mars's equatorial region.

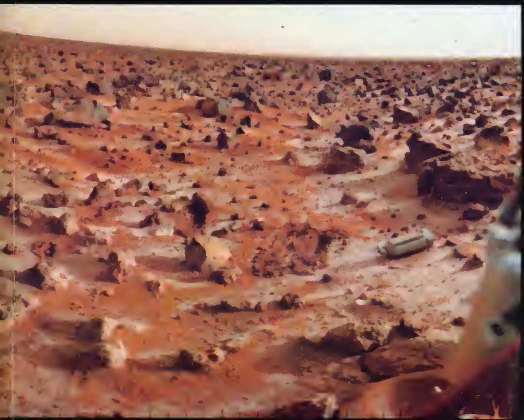
At this scale there is a link between the old and new faces of Mars. The dark blunt-headed shape of Sinus Meridiani, familiar through telescopes for one hundred years, appears with craters and canyons (lower left) discovered only in the modern era of spacecraft exploration. Many craters show distinctive light and dark patches caused by the accumulation of variously-colored dust on their downwind sides. The large "classical" markings visible here, however, have no obvious relationship to physical features on the surface, and their origin is still a mystery.



Frost on Mars—This image was obtained late in Viking 2's second winter on Mars, at a season equivalent to late February in the northern hemisphere on Earth. Frost formation is probably quite a complex process. During the Martian winter at Viking Lander 2's latitude of 48° North, nighttime air temperatures fall to a frigid −188° Farenheit, cold enough for the carbon dioxide atmosphere itself to start to freeze. Solid carbon dioxide (familiar to us as dry ice) probably accumulates on atmospheric dust grains already coated with water ice, the extra weight sending them drifting to the ground as a fine, invisible snow. Morning sunshine evaporates the dioxide frost but leaves the ice-coated dust grains to whiten the Martian surface. Now, as spring approaches, the increased warmth of the Sun is slowly evaporating the water ice, which remains only on the shaded northern sides of rocks and boulders. A second image taken 22 days later showed only tiny patches remaining.

This alien scene is punctuated by two reminders of the technological miracle that made it possible for us to experience this Martian winter—the discarded shroud of the Lander's sample arm and a part of its right footpad.

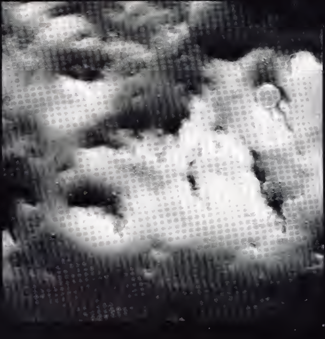
THE **VIKING** LEGACY



"Melted-Down" Mountain—Although at low resolution the cratered highlands of Mars's southern hemisphere are reminiscent of parts of the Moon, the resemblance disappears under the high-resolution scrutiny of the Viking Orbiter cameras. This 40-kilometer-wide image shows a mountain probably thrown up by the enormous impact that created the 1900-kilometer-diameter Hellas basin, which is big enough to be conspicuous from Earth through a small telescope.

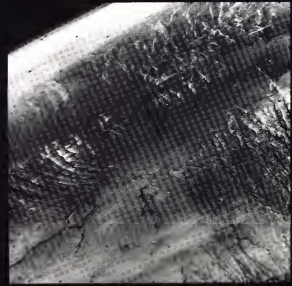
This mountain's present bizarre "melted down" appearance, which sets it apart from any lunar feature, is probably the result of solifluction, a gradual downhill creeping of ice-filled soil that happens in cold regions of Earth, too. As is so often the case, a process familiar on Earth turns up on Mars at a vastly grander scale. Here it seems to be destroying the entire mountain. A three-kilometer-diameter crater near the summit has been filled and material from its own walls is now slowly flowing towards the valley in long, dark tongues.

This sort of feature is just one of the many clues pointing to the presence of abundant ice below the Martian surface, ice that may one day be a valuable resource for human explorers.



Toward the Horizon—From 6000 kilometers above the Martian surface, early in its mission Viking 1 took this image of a 160-kilometer-wide swath of the volcanic Tharsis region. The uplift of the 8-kilometer-high "Tharsis Bulge," one of the major events of early Martian history, splintered the surrounding crust with innumerable parallel fractures, some of which are seen here partly buried by vast lava plains stretching toward a hazy horizon. White wisps along the sides of many of the fractures are unusual and puzzling. This is midsummer and only 30° north of the Martian equator, so frost is an unlikely explanation: the wisps are most likely to be ground-hugging clouds produced by the flow of air across the irregular surface. (The dark doughnut at the center of the image is not a Martian feature, but a flaw caused by a speck of dust in the camera optics.)

Horizon views like this capture the spirit of Mars better than any others. It is a cold, quiet place, a world as real as our own, alien but not unwelcoming. It is waiting for us.



A TALK WITH BURT EDELSON

Louis Friedman: Why did you, an executive in private industry, move to a government position in NASA as Associate Administrator for Space Science and Applications?

Burt Edelson: I was offered what seemed to be a great opportunity; a position in an agency I respected and at a level where it seemed possible that I could make things happen and get something done. Combining science and applications into a single office at NASA presented me with several opportunities to get some existing programs back on track and to start new and innovative ones. It has always been my goal to be in a position where I can contribute, I believe I can do just that at NASA.

LF: Do you feel that combining science and applications in the NASA organization is good for the agency and good for individual programs?

BE: Yes, I do. Much of the technology in the two programs is the same. Also, there's a great deal of scientific content in the applications program. For example, much of the applications program is based on understanding Earth as a planet. Earth science can be considered an extension of space science. Similarly, new developments in space exploration arise out of the applications programs. Many of the studies in comparative planetology have much in common with the objectives of our atmospheres and remote sensing programs looking at Earth. The common technology and the synergism of the science between the two programs will be more effectively utilized by the combination of science and applications into a single office.

LF: You were a member of The Planetary Society before coming to NASA. Why did you join the Society?

BE: I was working in the field of space technology—satellite communications—and was interested in how space technology was being applied to other fields. I've always been interested in planetary exploration. So as soon as I heard about The Planetary Society, I joined.

LF: Many recent actions point to the administration's having decided to shut down the U.S. planetary program: shutting off the *Pioneer* spacecraft, closing the Infrared Telescope Facility and the Lunar Curatorial Facility, cutting the number of planetary researchers and data analysis in half and cutting advanced technology. Will you help implement a policy to cut back this nation's exploration of the solar system?

BE: No, I didn't come to NASA to cut back on anything. I should point out that most of the examples you cited are under the research and analysis (R & A) and the Mission Operations and Data Analysis (MO & DA) budgets. Those budgets have been hard hit the past few years. Because of large projects like *Galileo* and the Space Telescope, there has been a tendency to consume the R & A and the MO & DA funds, which are flexible. But that's like eating your seed corn. One of the goals that I have in the fiscal year 1984 budget (which is the first one that I can affect) is to build the underlying research base up again. For example, I am going to try very hard to find funds to keep the *Pioneers* alive—possibly combining *Pioneer* operations with *Voyager* operations—and to keep the Lunar Curatorial Facility open. It's too late to prevent research scientists from being cut back in fiscal year 1983, but we're doing everything that we can to mitigate the problem and to correct the situation, starting in fiscal year 1984.

LF: What near-term possibilities do you see that may revitalize planetary exploration?

BE: Two new items that we are proposing for new starts in the fiscal year 1984 budget are the Solar Interplanetary Spacecraft (SIS) and the Venus Radar Mapper (VRM) [see pages 16 and 17]. The Venus Radar Mapper is a top priority candidate, provided that it can be done within the target budget guidelines of about $250 million. SIS is the first in a series of Observers which we plan to send to the planets.

LF: Weren't earlier versions of these missions rejected by the policy makers—the Venus Orbiting Imaging Radar (VOIR) and the U.S. spacecraft for the International Solar Polar Mission (ISPM)?

BE: No, those were *budget* decisions, not policy decisions. We are still playing an important role, in fact paying half the costs, in ISPM. And we have risen from the ashes of VOIR with the new Venus Radar Mapper, which will be a lower-cost mission accomplishing almost as much.

LF: The Planetary Society has funded some work in the SETI (Search for Extraterrestrial Intelligence) program, including the building of a receiver that has just been tested at the Arecibo Radio Observatory. We have started a program called the Mars Institute which will, with member support, coordinate a series of studies at the university level about Mars exploration, perhaps leading all the way to colonization of Mars. Do you think there's a role for the Society in funding research and possibly doing it cooperatively with NASA?

BE: I think that it is worthwhile for the Society to start these seed efforts because they're not the kind of things that are going to be done by the government. The initial investigations and exploratory research, including some system studies, focus attention and create interest, especially among the young people who are going to be running the space program 10 or 20 years from now. I think the SETI program is fascinating—it's the most interesting single question that we're posing today. It's delightful that The Planetary Society has taken an interest in it. On the other hand, I really don't see much opportunity for cooperative work. It's awkward for the government to work on an R & D program with a private society.

LF: So you still see the government role as principal to continuing space exploration?

BE: Oh, yes. Although you haven't asked me, I'll add a point here. Planetary exploration has to be internationalized in the future for two very good reasons. One, it's getting so blasted expensive that no single country can afford it, not even the United States (as we have seen). Two, nowadays other countries have good science and tech-

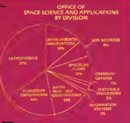
THE SOLAR INTERPLANETARY SPACECRAFT—The Solar Interplanetary Spacecraft is designed to carry a solar-coronograph/x-ray/extreme-ultraviolet telescope and other instruments into a heliocentric orbit just beyond and behind the path of the Earth about the Sun. The SIS would observe the Sun from the ecliptic (the plane cut by the orbit of the Earth), and the data it collects would supplement the information obtained by the European International Solar Polar (ISPM) spacecraft, which will observe the Sun from above its polar regions. Although the American spacecraft for the ISPM mission has been cancelled, the SIS could capitalize on the scientific payload planned for that spacecraft. The SIS project must be started in fiscal year 1984 to coordinate with the ISPM mission and to minimize costs by using existing hardware. If the go-ahead is given, SIS would be launched in 1987.

COMPUTER GRAPHIC BY
SUE KOVACH AND JIM BLINN
JPL/NASA

nology—that wasn't true a decade ago The European countries and Japan, as well as the Soviet Union, have made significant accomplishments in science and there's no reason in the world why scientific missions shouldn't be cooperative

LF: Do you feel competitive with other nations, and what effect do their efforts have on what we do?

THE NASA ORGANIZATION—NASA has recently been reorganized into six major areas, each headed by an Associate Administrator who reports to the NASA Administrator, Dr. James Beggs, and the Deputy Administrator, Dr. Hans Mark. These six areas and their Associate Administrators are:



Space Science and Applications—Dr. Burt Edelson
Aeronautics and Space Technology—Dr. Jack Kerrebrock
Space Transportation Systems—Gen. James Abrahamson
Space Transportation Operations—Dr. Stanley Weiss
Space Tracking and Data Systems—Dr. Robert Smylie
Management—Dr. Walter Olstad

Space Science and Applications includes the major divisions and budget allocations shown in this budget pie. NASA Goddard Space Flight Center and Caltech's Jet Propulsion Laboratory come under the jurisdiction of this office.

BE: Well, Mr Beggs, General Abrahamson and I just came back from meetings with the ESA (European Space Agency) and the CNES (Centre National d'Etudes Spatiales, the French space agency). We talked with them about cooperative programs. There is a great deal of interest, in fact eagerness, in cooperation After the ISPM experience [the U.S spacecraft in the International Solar Polar Mission was cancelled, leaving the European spacecraft to go it alone], we're a little bit shy of joint programs, but there's every possibility that cooperative programs can be carried out In the long run, we will generate some joint programs, too. There is already cooperation through Principal Investigators and Co-Investigators on missions and in the hardware and software of spacecraft and data systems ISPM, *Galileo*, the Space Telescope and the Infrared Astronomical Satellite are all examples

I'll be quick to say that there are areas of technology development in which we would not wish to work cooperatively with other nations. Probably the best example of that is NASA's program in satellite communications which is aimed primarily at establishing U.S leadership in this important field We're not particularly eager to share our technology with other nations in this field This thought has been articulated by the present administration science is international and cooperation in this field is good, while in development and control of our own technology it is important to maintain U S leadership

LF: How do you feel about large space ventures, such as the human exploration of Mars, a lunar base, asteroid landings, Mars sample returns and solar sailing ferries?

BE: I'm primarily an engineer and one of the most exciting things to me is that these so-called big science programs largely involve implementation—they're really big engineering programs. Once the scientists set the goals, the actual work in developing the instrumentation, the spacecraft, the launch system, and operations are major engineering feats

We are ready for a major new engineering endeavor—a mission to the Moon or one of the planets. The Solar System Exploration Committee [a NASA advisory body], under the leadership of Noel Hinners, has been wrestling with this problem and has made several recommendations People in several other fields are trying to come up with new initiatives There is a general dissatisfaction that we left the Moon untouched and unexplored after the *Apollo* program, that we are doing nothing with Mars after having made a magnificent approach toward it I believe that we should be involved in such an effort and that there will be one To answer about timing, I'd say that it will get started in the next two years and will be a mission that we will try to run during the 1990's.

LF: Will this be a national or international effort?

BE: Well, I'm not sure what type of mission it will be—possibly a Mars landing or sample return It will involve manned space flight to some extent. I'm not sure that man will actually go to the planet, but he will be involved in the support of the mission The mission could start in 1986 or 1987 and would be largely a national mission with opportunities for foreign participation, rather than a joint international mission It's just too hard to internationalize something as big as that We may internationalize smaller missions but the big ones we should keep for ourselves to lead, but we would allow some degree of international participation in experiments and instrumentation

LF: This is a startling revelation

BE: The opportunity is there, and we have the capability There is plenty of dissatisfaction in the science community over what we are not doing We're generating the technology and the drive, we're starting to get studies, like the SSEC one, that are pushing us along The ferment and generation of technology will come together in the next two or three years in a major

planetary mission like *Apollo* or *Viking*. Such a program would generate U.S. pride in our own accomplishments and U.S. prestige among all nations of the world. A major mission would exploit U.S. engineering and provide a focal point for high technology development in the future. My estimate is that these forces will come together in two or three years to start a major new program. Everything is right for it.

LF: There's been a lot of talk about a new emphasis on military support within NASA. Do you think NASA is going to be concentrating on military support and doing less in the development of civilian applications and science? Do you feel your office has a role in military support activities?

BE: Yes, I do think that the Office of Science and Applications has an important role in relation to military space. The military is just one application of space technology. Most of the military applications are similar in engineering terms to the civilian applications of space. The military has requirements for satellite communications, Earth-viewing platforms, and instruments, detectors and microwave sensors of different kinds. We would develop and apply the technology for military uses as we would for civilian uses. There will be a growing involvement of NASA with the military that is just a manifestation of the maturity and utility of space technology. One of the principal users of advanced technology is the military. I would not agree with your assumption that if NASA's military involvement were to increase, NASA's own uses will necessarily diminish. I think the military and civilian uses will be self-supporting and will result in an enhancement and an increased opportunity for NASA to develop civilian applications.

LF: The space station is being discussed as a new initiative for human activity in space. How might it be useful to space science applications and do you think that there is a danger of such an initiative further squeezing out science and applications programs?

BE: I'll try to attack that question head on. One of the first things I did when I came into the agency in March was to address a question to Bruce Murray at JPL and Tom Young at Goddard as to what the benefits for science and applications might be from a space station program. Task forces were organized at both centers, and they made recommendations to me in April which indicated that they saw benefits for science and applications—for Earth-viewing applications, for astrophysics, for stationary orbit science and applications and even for planetary missions—if the space station were configured in certain ways. For planetary science, a space station could make an important contribution if, in low-Earth orbit, it was possible to assemble, check out and test large, unmanned, automated platforms. There are such tasks as assembly, erection, alignment of large antenna and feed systems, adjustment of thermal control systems, and calibration of instruments that can't be done on the ground. This would allow us to assemble complex autonomous platforms and send them to the planets having been checked out and tested in low-Earth orbit. We could build much more complex stations. That's the kind of thing that the space station program could contribute to science and applications.

We have taken the JPL and Goddard inputs and fed them to both the Space Applications Board and the Space Science Board [of the National Academy of Sciences] and we will get their expressions as to how a space station can be useful to science and applications. Then we're going to take the results of those efforts and feed them into mission analysis studies being done by aerospace contractors. We will require them to consider these requirements and to show how the configurations that they're recommending can benefit science and applications. We hope to influence the space station program to help us do our missions more efficiently and to undertake new missions.

LF: Are you optimistic about the U.S. space program?

BE: Yes, optimistic and enthusiastic. Even more, I'm going to work to create the new enterprise. I would recommend that The Planetary Society publicize the recommendations of the SSEC in your journal, try to get a debate going, and to form a consensus—to get the same kind of support for a planetary program that the astronomical community has got from the Field Committee [a committee of the National Academy of Sciences] report. You'd be doing something really constructive and helpful in keeping American planetary exploration healthy and productive. □

THE VENUS RADAR MAPPER—Thick, unbroken clouds successfully hide the surface of Venus from spacecraft and telescopes that observe in the visual spectrum of light. But an instrument called Synthetic Aperature Radar (SAR) can use radio waves to "see" through cloud cover to the surface of planets. The Venus Radar Mapper is a proposed mission that would use SAR to survey 92 percent of the surface of Venus. Images of photographic quality would be returned to Earth, providing detailed data of the geology of the shrouded planet.

In size, mass and composition, Venus is similar to Earth. But its thick, noxious atmosphere and scorching surface temperatures are anything but Earthlike. What little we know of its geology suggests that Venus's surface was formed by processes very different from those that shaped Earth. Why did such similar planets evolve so differently? The Venus Radar Mapper could provide the detailed information needed to begin to answer this question.

Mission planners are looking toward a 1984 start for the project, with launch in March or April, 1988 and arrival at Venus that July.

PAINTING BY ALAN GUTIERREZ FOR JPL/NASA

News & Reviews

by Clark R. Chapman

I've been watching the sunset this evening from Kitt Peak National Observatory. The northwestern sky is suffused with the purplish-orange glow of the thick cloud of sulfuric acid in the stratosphere resulting from the eruption of the Mexican volcano El Chichón this spring. To the south, the telescope domes are poised beneath a sky that is ominously black. Crackling lightning bolts and thunder approach the mountain from the southeast, an all-too-common occurrence during the Arizona summer "monsoon."

Instead of beginning my planned observing routine, I am inside writing this latest installment of "News and Reviews." Such are the impediments to astronomy in what is really one of the most cloud-free spots in North America. Even on a clear night, stars and planets appear blurry and pulsating through the eyepiece of a telescope, as if viewed through a fishbowl or across the heat of a campfire. And some of the most important spectral bands for observing celestial objects, for example the far ultraviolet, are blocked by the Earth's atmosphere.

So, on a night like this I am reminded of the dreams of astronomers of generations past to reach above the air and observe the heavens from the unimpeded vantage point of outer space. The dawning of the Space Age brought the first hopes that the dream might eventually be realized. After a successful series of small orbiting astronomical satellites, a project is now underway that will soon make the dream a reality.

A NASA project, conceived as the "Large Space Telescope," suffered some budgetary parings and emerged, in its 1977 congressional authorization, as simply the "Space Telescope." Now much of the telescope is built, along with its initial complement of scientific instruments. The schedule looks good for a 1985 launch by the space shuttle. It will revolutionize optical astronomy.

In the July issue of *Scientific American*, two creators of the Space Telescope describe the project's history and the six instruments on board. They speculate on some of the marvelous findings that may be in store for us once this precision telescope first looks into the reaches of the cosmos. Although not so big as some of the giant ground-based telescopes, the Space Telescope may detect stars a hundred times fainter than can be seen with the 200-inch Palomar telescope. With its advanced electronic arrays of charge-coupled devices (CCD's), the planetary camera may chart storms on Jupiter with a resolution that can be exceeded only by a close planetary flyby. Turned toward distant galaxys and quasars, the telescope will be able to measure the spectra of objects too faint to have been seen before.

The farther astronomers can pierce the immense universe, the closer their measurements will come to telling about the properties of the universe shortly after the beginning of time. The Space Telescope promises to address a host of questions already raised by ground-based observations, and it will undoubtedly reveal new fascinating phenomena that the next generations of astronomers will try to comprehend.

The Politics of Space

Earlier today I showed a young Norwegian astronomer around Kitt Peak. He was awed by the magnificence of the facilities and the sheer size of the McMath Solar Telescope. But the observatory reflects America's dedication to science in decades now past. Today the paint is falling from the sides of the McMath tower, and funds cannot be found to refurbish it. I had to tell the foreign visitor that several telescopes we walked past are now closed due to lack of funds to operate them. Even in a technological wonderland like Kitt Peak, political reality constantly intrudes.

Much "forefront" science being done in this country and abroad is necessarily supported through government funds. Groups like The Planetary Society can foster specific small projects. But much of modern science is too large and complex an enterprise to benefit from the largesse of benefactors, and private enterprise restricts its major investments to the more practical and applied sciences, where profits can be returned in the short term.

Politics during the past year have been particularly grim for planetary science, as readers of *The Planetary Report* well know. You can keep up with "space politics" by reading several popular magazines on science. Earl Lane, writing in the July *Omni*, gives a succinct and accurate account of how (and for what disillusioning reasons) the planetary program was saved from virtual extinction last winter.

Robert Cowen of the *Christian Science Monitor* often comments on space politics in his thoughtful column in *Technology Review*. In the July issue, he raises the controversial issue of the proposed space station. According to Cowen, this is an area where the Soviets are far ahead of the west. Within NASA, debate rages about whether the chief purpose of any space station project will be to advance the civilian goals for which NASA was created, or instead to foster the militarization of space. As Cowen remarks, soon there is "undoubtedly going to be a major political debate over the long-range goals of the U.S. space program."

The Climate of Our Own Planet

Just as the mysterious polar terrains on Mars provide evidence for a cyclical climate of the Red Planet, so the geology of the northern hemisphere on Earth reveals that our present temperate climate is an anomaly amid a cycle of ice ages. Writing in the weather-watcher's magazine, *Weatherwise* (the June 1982 issue), R. V. Fodor reviews theories on why ice ages happen. During the past decade, scientists have finally agreed that "astronomical" effects dominate our world's long-term climate. The ice ages result from surprisingly small changes in the tilt of our planet's axis, the periodic wobbling ("precession") of the axis, and varying eccentricity of the orbit.

The simple fact that our climate is so sensitive to small changes in received sunlight, due to astronomical geometry, raises questions anew about whether other factors may also affect planetary climate. For example, what about that stratospheric cloud of volcanic residue that has dimmed the stars above Kitt Peak? According to a recent issue of *Time*, planetary physicist Brian Toon of NASA's Ames Research Center believes that the cloud may diminish sunlight over the whole northern hemisphere by as much as one to two percent, reducing the average temperature by as much as 1° Farenheit, and perhaps causing early frosts this autumn. The slight cooling may last a year or two.

Clark R. Chapman, incoming chairman of the Division for Planetary Sciences of the American Astronomical Society, regularly measures asteroids using telescopes at observatories like Kitt Peak.

Society Notes

by Louis Friedman

Recently I examined several polls which surveyed public opinion about space exploration. Often such polls are self-serving and an inaccurate means of conveying information. However, a careful reading of the polls can be instructive about public attitudes. One of the most complete analyses of this subject was done by the Congressional Office of Technology Assessment ("Civilian Space Policy and Application," OTA-STI-177, available for $9.50 from the U.S. Government Printing Office, Washington, D.C. 20402). They noticed an increasing trend of support for space exploration, coinciding with a growth of public interest groups like The Planetary Society. There is a delicate consensus in favor of the space program, but that consensus could break up over funding and ideological issues. They conclude that "the recent upswing in opinion in favor of the space program appears significant."

The size and rapid growth of The Planetary Society testify to this public support for planetary exploration. As of mid-summer 1982, we have 111,000 members. And this is continuing support, our members are renewing at a rate of nearly 60 percent. This is a very good rate for an organization beginning its second year; renewals for some membership organizations run at 30 percent even after they are well established. But all is not rosy: the cost of direct mail solicitation of new members has increased a great deal and the rate of return continues to decrease due to both the downswing in the economy and our efforts to reach segments of society that are less than fully enthusiastic about planetary exploration.

We recently attended the conference of the International Planetarium Society held in Vancouver, British Columbia. We are attempting to set up liaisons with planetariums around the country and the world so that they, and science museums, can become local centers of activity for The Planetary Society. Members can give this program a boost by contacting planetariums and science museums in their area, urging them to contact us, to offer *The Planetary Report*, and to feature information about the Society in their gift shops, book stores, etc.

Author and journalist Harry Ashmore has resigned from The Planetary Society's Board of Advisors. In doing so, Mr. Ashmore wrote: "I was pleased to have an opportunity to help get the Society and its *Planetary Report* off the ground. I think the publication has developed into a first-rate effort, and a notably handsome product."

Mr. Ashmore received a Pulitzer Prize in 1957 for a series of editorials in support of school integration, written for the *Arkansas Gazette*. His recent book, *Hearts and Minds—the Anatomy of Racism from Roosevelt to Reagan*, continues his lifelong examination of racism and its causes. In 1959, he moved to Santa Barbara, California, to help found the Center for the Study of Democratic Institutions. When the idea of The Planetary Society was presented to him in early 1980, Mr. Ashmore became a great enthusiast. We were particularly pleased and honored to work with Mr. Ashmore because of his insight into the importance of space exploration to cultural and social creativity.

As the Society nears the end of its second year, we anticipate other changes in our Board of Advisors to reflect a continuing infusion of new viewpoints, as well as to permit the energies of some members to be focused on other activities. We hope very much to keep up our past associations while making new ones. □

Celebrate Interplanetary Flight!

The Planetary Society will celebrate the 20th anniversary of interplanetary flight with a special symposium, reception and commemoration in Washington, D.C. on December 13 and 14, 1982. These events are open to all Planetary Society members. A commemoration ceremony for *Mariner 2* flyby of Venus on December 14, 1962 will be conducted by Dr. William H. Pickering, former director of the Jet Propulsion Laboratory and one of the leading pioneers of the nation's space program. The ceremony and a reception will be held at the National Air and Space Museum of the Smithsonian Institution at 7:00 p.m. Monday night, December 13th. Dr. Carl Sagan, President of the Society, Dr. Jacques Blamont of the French space agency, and Isaac Asimov, noted author, will look back on the first 20 years of interplanetary flight at a symposium to be held in Lisner Auditorium at George Washington University at 4 p.m., Tuesday, December 14th. Drs. Blamont and Asimov are Advisors to the Society.

On Tuesday night, December 14th, at 7:30 p.m., a dinner will be held at a major Washington hotel to honor the team of scientists, engineers and managers that sent *Mariner 2* to Venus, and the symposium participants. Dr. Bruce Murray, Planetary Society Vice President, and Dr. Sagan will speak about the future of planetary exploration.

Tickets for all three events are limited and must be purchased in advance. The event is being held principally for Society members. The costs are:

Event A	Commemoration and Reception	$10.00
Event B	Symposium	$ 5.00
Event C	Dinner	$50.00
Special package of all three events		$60.00

Please send your reservation and payment to The Planetary Society, P.O. Box 91327, Pasadena, CA 91109. Your tickets will be mailed to you. The Society has reserved a block of rooms at the Channel Inn Motel, conveniently located less than a mile from the Smithsonian. Discount rates for Society members will be $60.00 for a double room, $54.00 for a single, with no charge for young children or parking. Reservations should be made directly with the Inn, *before November 15*, and must include mention of The Planetary Society. Reservations will be held only until 4:00 p.m. on the day of arrival unless a deposit for one night has been made by check or credit card (include type of card, number and expiration date). Send reservation to: Channel Inn Motel, 650 Water St., Washington, D.C. 20024.

Space Policy Meeting in Boulder

On Tuesday evening, October 19, 1982, The Planetary Society will cosponsor a discussion of public policy toward the planetary program at the annual meeting of the Division for Planetary Sciences of the American Astronomical Society.

Some of the new faces in space policy will be featured this year: Jesse Moore, head of NASA's planetary program office; Burt Edelson, Associate Administrator for Space Science at NASA; and Lew Allen, the new director of JPL, have been invited to appear on a panel along with Drs. Don Hunten and Tom Donohue of the Space Science Board of the National Academy of Sciences and Representative Tim Wirth of Colorado.

The session is open to all Planetary Society members (please bring your membership card) and will be held at the Hilton Harvest House Hotel at 8:30 p.m. on October 19th.

Questions & Answers

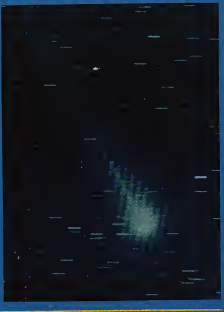
IS IT POSSIBLE TO DIVERT *one of our existing satellites to an encounter with a comet?*
—*David Whittall, Tustin, Calif.*

ON JUNE 10, 1982, the engines of the International Sun-Earth Explorer-3 were fired, sending the spacecraft on a trajectory that could take it to an encounter with the Comet Giacobini-Zinner in 1985. ISEE-3 had been monitoring the solar wind from a "halo orbit" around libration point L_1 for the past four years. (This libration point is a place where a spacecraft can be situated so that it remains in the same position relative to the Earth and Sun.) The satellite is currently on a mission to the Earth's magnetotail, the portion of the magnetosphere blown out behind the planet by the solar wind. ISEE-3 will follow a figure 8 trajectory through the magnetotail and should return new information on the interaction of the Earth and the solar wind, including data on phenomena associated with the aurora.

Several researchers have suggested that it is possible to send the spacecraft on to encounter Giacobini-Zinner. Sometime between Decembers 1983 and 1984, the spacecraft would swing by the Moon and be deflected into an orbit that would send it to a rendezvous with the comet on September 11, 1985, six months before the Japanese, Soviet and European spacecraft will encounter Halley's Comet.

ISEE-3 was designed to monitor the solar wind, the stream of ionized particles flowing out from the Sun, so it is not equipped to photograph the comet. However, it is the interaction of the comet nucleus with the solar wind that produces the long, graceful tails which we associate with comets, so the information that the spacecraft is able to return will be invaluable in aiding our understanding of the behavior of these periodic visitors.

As appealing as this cometary mission seems, there is opposition to the project. If ISEE-3 is sent on to Giacobini-Zinner, it would be unable to return to its mission of monitoring outpourings from the Sun. The Space Science Board of the National Academy of Sciences has weighed the alternatives and endorsed the plan to send the spacecraft on to the comet. The final decision on where to send ISEE-3 will be made by NASA.—*Ed.*
Thanks to Edward J. Smith at JPL.



THE COMET GIACOBINI-ZINNER, PHOTOGRAPHED IN ITS 1959 APPARITION BY ELIZABETH ROEMER OF THE UNIVERSITY OF ARIZONA.

WHAT'S THIS ABOUT A NEW *planet being discovered in our solar system?*
—*James Ryan, Los Angeles, Calif.*

ALTHOUGH NOTHING HAS yet been discovered, there is a real possibility of a tenth planet, or stellar object of some sort, beyond the orbit of Neptune. This object could be either gravitationally bound to the Sun, and hence likely to have formed with the solar system, or it could be a rare interstellar visitor that just happens to be passing through the solar neighborhood at this time.

The most persuasive evidence that there is something out there comes from data published in *Icarus* in 1980 by astronomers at the United States Naval Observatory. They compared their best ephemerides of Uranus and Neptune against observations extending to 1978 and found unexplained motions for both planets. With the discovery of Pluto's satellite Charon by Christy and Harrington in 1978, it became clear that the mass of the Pluto-Charon system is much too small to have any observable effect on Uranus or Neptune. As a result, the problem of reconciling the motions of those two giant planets with observation has become more acute. We are reasonably certain that our gravitational model of the outer solar system is incomplete, but we are unable to conclude that a trans-Neptune body is the cause of the difficulty. We have to remain open to other possibilities.

The chief argument against a tenth planet is that it has not been seen, although dedicated searches have been carried out by Clyde Tombaugh, the discoverer of Pluto, as well as by Tom Gehrels of the University of Arizona and Charles Kowal at Caltech. Kowal is searching down to a limiting visual magnitude of 20, but his survey is far from complete. Tombaugh completed his survey around 1945 and concluded that there are no unknown planets brighter than magnitude 16 in the ecliptic. In comparison, Neptune would have a magnitude of 16 at a distance of 200 AU (Astronomical Units, or the distance from the Earth to the Sun), in contrast to its actual distance at opposition of 29 AU and visual magnitude of 7.7.

Other bodies besides planets have been seriously considered as perturbing bodies. These range from substellar objects of a few Jupiter masses, to dark neutron stars, to supermassive black holes. The evidence that the Sun might have a stellar dark companion or passing visitor comes from an examination of the spatial distribution of pulsar spin-down rates by Edward R. Harrison of the University of Massachusetts. His findings indicate that the Sun is accelerating in the general direction of the galactic center. This could be caused by a solar companion or passing star.

Fortunately, within the next few years our model of the solar system may become complete. We are using the orbits of *Pioneer 10* and *11* to search for a trans-Neptune body. The action of an unknown force on the solar system should be revealed by the distant *Pioneer* spacecraft after three or four years of analysis. At the same time, the Infrared Astronomical Satellite (IRAS) will search the solar neighborhood for substellar objects. According to Ray T. Reynolds at Ames Research Center, IRAS could easily detect another planet the size of Jupiter out to 16,000 AU, or a substellar object (a brown dwarf) to much greater distances.

All in all, the next few years will be active ones for planet searchers. The various techniques, involving orbital dynamics as well as visual and infrared surveys, should produce some interesting and scientifically important results.
—*John D. Anderson, JPL*

WASHINGTON WATCH

by Louis Friedman

President Ronald Reagan announced a national space policy on July 4, 1982. The policy deals with both civilian and military space activities and is the result of a ten-month interagency review by the Office of Science and Technology Policy, headed by the President's Science Advisor, Dr. George Keyworth. The President announced no major new initiatives in space exploration, but reaffirmed support for activities already underway, such as the space shuttle, space applications and general space science. The new policy reiterated previous policies for a "balanced strategy of research, development, operations and exploration for science, applications and technologies." In the military space program, the President announced that the United States will proceed with the development of an anti-satellite capability.

In a background briefing held prior to the President's speech about the new space policy, a "senior administration official" noted that the administration has established an interagency group to "implement the policy and . to set the course for our space program." The official said that a manned space platform is one of the programs under consideration, but no decision has yet been made. Neither space science nor planetary exploration were discussed at the briefing.

In late July the President and Congress finally agreed on the budget for fiscal year 1982. The "urgent supplemental" bill signed by President Reagan on July 18th included a redirection of the *Galileo* mission—back onto the *Centaur* upper stage with a launch in 1986 rather than 1985. The *Centaur* is planned to be a far more capable rocket than the Inertial Upper Stage (it uses propellant with higher exhaust velocity) and it would take *Galileo* on a direct trajectory to Jupiter, rather than requiring the ΔVEGA trajectory used with the IUS. (See the March/April, 1982 issue of *The Planetary Report* for a discussion of the ΔVEGA trajectory and the IUS) Although the launch of *Galileo* would be delayed for one year, by taking the shorter path to Jupiter the spacecraft will arrive one year ahead of its ΔVEGA schedule.

JPL engineers are pleased with the higher capability launch system although they are concerned that the late start on the more expensive *Centaur* might introduce still more uncertainty into the program. The *Centaur* has been one of the workhorses of the U.S. missile stable; it has been used as an upper stage on *Atlas* and *Titan* launch vehicles for many years. However, its design will have to be modified to allow it to be used on the space shuttle and this will require an estimated $200–250 million contract to General Dynamics, builder of the vehicle. General Dynamics claims that they can do the modifications in time for the *Galileo* launch—the main fuel tank must be made wider to hold more fuel and the rocket must meet rigid shuttle safety standards. Planetary scientists and engineers are hoping that they are right, for *Galileo* is the only U.S. mission approved for the 1980's.

Meanwhile, with the 1982 budget finally settled, Congress will get down to preparing the 1983 budget and appropriations. One action under consideration is the reversal of the 1982 decision to put *Galileo* on the Centaur, this would force the spacecraft back on the IUS. Information on the course of budget, authorization and appropriations bills in Congress is included on the Society's information lines: from east of the Mississippi, call (213) 793-4328; from west of the Mississippi, call (213) 793-4294.

With 1982 and 1983 commanding our attention, it might seem strange for us to bring up 1984. But *this is the time to pay attention*, for the fiscal year 1984 budget is currently being negotiated by the Office of Management and Budget (OMB) and NASA. By December it will be in its final form for presidential review and presentation to Congress on January 20, 1983. This budget will contain several items of extreme concern to Planetary Society members, including the restoration of research and operations funds for planetary science. In the 1983 budget these funds were down 28 percent below their 1982 level and down 40 percent below the 1981 level. The goal for 1984 is to restore the funds to their 1982 level and permit two new project starts: the Venus Radar Mapper and the Solar Interplanetary Spacecraft (see pages 16 and 17).

To make your views on the Venus Radar Mapper, planetary research funds and other space topics known to the administration before the budget is finalized, write either to the President, White House, Washington, D.C. 20500, or to Dr. George Keyworth, the Science Advisor, Executive Office Building, Washington, D.C. 20501.

At the end of July, before the Senate and House Authorization Committees met to consider NASA's program for fiscal year 1983, NASA Administrator James Beggs sent a letter to Ronnie Flippo, chairman of the House subcommittee responsible for the NASA authorization. In that letter, Mr. Beggs assured Rep. Flippo that he supported the planetary program and promised to apply internal reprogramming within the agency so that the *Pioneer* spacecraft would continue to be tracked and that the Infrared Telescope on Mauna Kea, Hawaii, would not be closed. He also promised to increase support for planetary research by scientists.

Although the internal reprogramming to which Mr. Beggs alluded would restore only 25 percent of the funding necessary to keep the planetary program at a minimal level, the fact that such a letter had to be sent and that the agency was taking internal measures to renew the planetary program, even with the absence of extra funds, was clearly a victory for Planetary Society members. The NASA commitment should lend support to those in Congress trying to increase planetary program funding and make possible a new start for the program in the fiscal year 1984 budget. I believe it shows that individual efforts from Planetary Society members, as well as the existence of The Planetary Society itself, has made a difference. □

THE SOLAR SYSTEM IN

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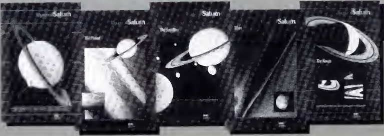

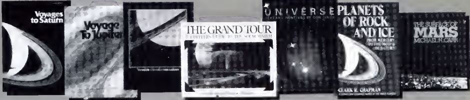

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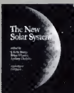

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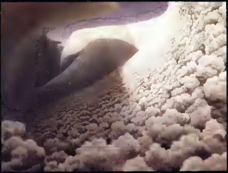

JOVIAN CLOUDS—Relatively white bands of clouds encircle the planet Jupiter, cut by relatively blue "canyons" in the clouds. In these paintings, artist Don Davis imagines how these cloud canyons would look from two perspectives. Both the color contrast and the overall "blueness" of the scene are exaggerated relative to average Jovian conditions.

Don Davis specializes in painting astronomical subjects. He lives and works in Mountain View, California. In addition to his space artwork, Mr. Davis photographs clouds, and this interest has influenced his painting. He is currently working on a book of his space art.

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